

R. A. BAGNOLD: A BIOGRAPHY AND EXTENDED BIBLIOGRAPHY

COLIN R. THORNE AND PHILIP SOAR

Department of Geography, University of Nottingham, NG7 2RD, U.K.

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ABSTRACT

1996 is the centenary of the birth of Brigadier Ralph Alger Bagnold, FRS. To mark this important anniversary this paper presents a short biography of Bagnold and an extended bibliography of his published work. The purposes of the paper are firstly, to present a synthesis of the life and significant discoveries made by Brigadier Bagnold, secondly, to communicate something of the character of the man and his work to generations of researchers who have not had the chance to meet him at first hand, and finally, to use this *Technical Supplement and Software Bulletin* to make summaries of his theories, empirical findings and views on science accessible to students and scholars of physical geography, geomorphology and engineering.

KEY WORDS aeolian processes; Bagnold; beach processes; bedload; deserts; dunes; exploration; fluvial processes; ripples; saltation; sediment transport; suspended load; turbidity currents; stream power; waves

INTRODUCTION

Brigadier R. A. Bagnold occupies a unique niche in the history of exploration, warfare and geomorphology during the 20th century. This is the case because, while many individuals have played important roles in each of these areas of human endeavour, Bagnold alone has played a globally significant role in all three. 1996 is the anniversary of Bagnold's birth, a timely occasion upon which to reflect upon his life and science and particularly, from the perspective of ESP&L, to take stock of his scientific contributions to the study of geomorphological processes and landforms.

Bagnold is especially well known for his exploration of the Libyan Desert during the 1920s and 30s, his pioneering work describing the physics of windblown sands and his subsequent application of his geographical and geomorphological knowledge in leading the Long Range Desert Group deep into enemy territory during the Second World War. However, it was not until his retirement from the army after the Second World War that he concentrated on research, leading to hallmark papers dealing with sediment movement on beaches and in the near-shore zone, the fluid mechanics of sediment auto-suspension in turbidity currents, and the application of the stream power concept to the explanation and prediction of sediment transport by rivers. Additionally, he also made original and significant scientific contributions to the study of breaking waves, closed-conduit hydraulics and flow resistance in meandering open channels.

While most readers will be familiar with some, or even perhaps all of Bagnold's work, few will have had the chance to meet him personally and so enjoy at first hand his approachability and his appealing, dry sense of humour. Yet Bagnold should also be remembered for his human qualities, his robust personality and his ability to puncture and deflate pomposity whenever he encountered it.

With these goals in mind, the remainder of this paper provides a short biography as the basis for students and researchers interested in fluid motion and sediment transport at the earth's surface to familiarise themselves with the life, science and personality of Brigadier Bagnold. It then presents an overview of Bagnold's contribution to the science of geomorphology. Finally, the paper presents in electronic form a bibliography,

extended to include abstracts and précis of his published work, that should serve the purposes both of whetting the intellectual appetite and providing an accurate reference to the complete articles.

BRIEF BIOGRAPHY

Ralph Alger Bagnold was born on 3 April 1896 in Davenport, England. Bagnold's Father (Colonel Arthur Henry Bagnold, C.B., C.M.G.) was then a Major in the Royal Engineers and had already seen active service in Cyprus, South Africa, Egypt and the Sudan while his paternal grandfather had been associated with the Honorable East India Company.

Even before attending school, young R. A. Bagnold voyaged by sea to Jamaica at the age of 3 and acquired an early appetite for adventure and exploration.

Commissioned as an officer in the Royal Engineers in 1915, Bagnold served in the trenches of France and Flanders during World War I. He subsequently took leave from the Army to earn an honours degree at Cambridge, and then, rejoining the Army, he served in Egypt, India and China. However, Bagnold's thirst for life's adventures and his exploratory nature led to voyages into the Atlantic from Ireland, to forays into the Libyan Desert and the Sinai from Egypt, to Kashmir from the Northwest Frontier, and to Siam and Cambodia from Hong Kong.

While stationed in Egypt, he began exploring the vast depths of the deserts in a Model T Ford with other bachelor officers. Eventually, their trips evolved into serious large-scale geographic exploration into unmapped areas of the desert. They developed techniques for taking these simple automobiles deep into the deserts without getting completely stuck or lost. They devised ingenious methods for navigating, conserving water and 'reading the land'. Ordinary compasses are difficult to use while driving in that type of rugged country, so Bagnold invented the very dependable 'sun compass'. Later, it became standard issue to the Egyptian Survey geologists and geographers.

Bagnold retired from the Army in 1935 to devote full time to his burning desire to understand the physics of sand dunes. He published an exciting chronicle of his desert explorations called *Libyan Sands* (Bagnold, 1935). It was republished recently (1987) with an inspiring new Epilogue written by Bagnold. In 1941, he published his second book entitled *The Physics of Blown Sand and Desert Dunes*, which remains a classic in the field even today.

Just prior to the Second World War, Bagnold expanded his interests to include studies of the movement of solids in flowing water and completed some laboratory experiments at Imperial College.

In 1939, war broke out in Europe and he was immediately called back to service. Though posted to East Africa, a collision at sea diverted him to Cairo. There, following Bagnold's direct persuasion of General Wavell, he established the exclusive, self-contained Long Range Desert Group (LRDG). Bagnold outfitted, sustained and commanded the LRDG deep into hostile territories behind enemy lines. There, the LRDG mapped and scouted enemy movements while creating frequent havoc for enemy supply convoys and aircraft.

The significance of Bagnold's military career is highlighted by the following excerpt from General Wavell's official dispatch of October, 1941:

'I would like to take this opportunity to bring to notice a small body of men who have for a year past done inconspicuous but invaluable service, the Long Range Desert Group. It was formed under Major (now Colonel) R. A. Bagnold in July 1940 to reconnoitre the great Libyan Desert on the western border of Egypt and the Sudan. Operating in small independent columns the group has penetrated into nearly every part of desert Libya, an area comparable in size with that of India. Not only have the patrols brought back much information, but they have attacked enemy forts, captured personnel, transport and grounded aircraft as far as 800 miles inside hostile territory. They have protected Egypt and the Sudan from any possibility of raids, and have caused the enemy, in lively apprehension of their activities, to tie up considerable forces in the defence of distant outposts. Their journeys across vast regions of unexplored desert have entailed the crossing of physical obstacles and the endurance of extreme summer temperatures, both of which would, a year ago, have been deemed impossible. Their exploits have been achieved only by careful organisation and a very high

standard of enterprise, discipline, mechanical maintenance and desert navigation. The personnel of these patrols was originally drawn almost entirely from the New Zealand forces; later officers and men from British units and from Southern Rhodesia joined the Group. A special word of praise must be added for the R.A.O.C. fitters whose work contributed so much to the mechanical endurance of the vehicles in such unprecedented conditions.'

So important were the accomplishments of the LRDG that Bagnold rose to the rank of Brigadier. He retired once again in 1944 and after a few years as Director of Research for Shell Oil, he devoted all of his efforts to extending his research beyond the movement of sands by wind and tackled the physics of the movement of all granular materials moved in any fluid. His primary goal was to eliminate the empiricism that so long dominated the difficult problem of describing the transportation of debris in water. He wished to derive an explanation based on the physical principles of hydraulics, fluid mechanics and particle physics.

He produced a series of papers on the topic that were published by the U.S. Geological Survey. One of his most significant is entitled 'An Approach to the Sediment Transport Problem from General Physics' (Bagnold, 1966). In the field of oceanography, he has studied the motion of sand on beaches and in the nearshore zone (Bagnold, 1963). He has also described the hydraulics of submarine density currents (Bagnold, 1962). In geography, his desert explorations throughout Libya and the Sinai earned him the Founder's Gold Medal from the Royal Geographical Society. In hydraulics and river mechanics, the National Academy of Sciences awarded him with the G.K. Warren Prize. He was also decorated for his invaluable service to his country.

SCIENTIFIC CONTRIBUTIONS

Brigadier R. A. Bagnold possessed a truly unique desire and ability to evaluate extremely complex phenomena through the use of pure physics supported by practical experimentation and sound mathematics.

Described by his close colleagues and friends as a perceptive intellect who was ready to accept 'the irresistible challenge' and one who received inspiration from 'the thrill of the unknown', the Brigadier was also known as a rugged, independent, self-sufficient, yet modest, gentleman. His election to Fellowship of the Royal Society of London in 1944, and of Imperial College of London in 1971, together with his receipt of the G.K. Warren Prize from the U.S. Academy of Sciences in 1969, the Penrose Medal from the Geological Society of America in 1970, the Wollaston Medal from the Geological Society of London in 1971, an honorary D.Sc. from the University of East Anglia in 1972, the Sorby Medal from the International Association of Sedimentologists in 1978, and the David Linton Award from the British Geomorphological Research Group in 1981 are indicative of Bagnold's distinguished international scientific stature.

The conception and production of a variety of practical scientific instruments was entirely incidental to his various exploits. The 'Desert-sun compass', the 'Instant-reading, multi-tube manometer', and the 'Piezo-electric pressure gauge', are but a few examples of his creativity (refer to Bagnold, 1953). Bagnold grew up with a father who was not only a Colonel in the Royal Engineers, but who also insisted that a properly equipped workbench should form an essential element of any library or study.

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There follows a bibliography of Bagnold which is accompanied, on the enclosed disk, by annotations, abstracts and, where appropriate, key paragraphs from the papers, journal articles and books. The file is called, simply, BAGNOLD.DOC and should be accessible from most word processors.

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